New resonances in B-meson decays

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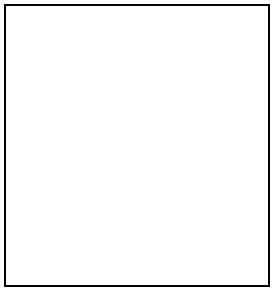

The $X(3872)$ and $Y(3940)$ properties and decay modes from Belle are reviewed and the results on a search for the decay $B^+ \to h_c K^+$, $h_c \to \eta_c\ \gamma$ at Belle are presented.

1 Introduction

B-mesons have proved to be a rich source of new particles. The B-factories at KEK (Belle) and SLAC (BaBar) extensively use the exclusive production of J/ψ, χ_{c1} and η_c charmonia for the CP violation measurements. In addition to these conventional charmonia Belle observed the production of $\eta_c(2S)$ [1] and $\psi(3770)$ [2] in exclusive $B \to (c\bar{c})K^+$ decays. Belle and BaBar also observed inclusive χ_{c2} production in B decays[3]. In 2003, by analyzing the $B^+ \to J/\psi\ \pi^+\ \pi^-\ K^+$ decays, Belle observed a narrow charmonium-like new state (denoted as $X(3872)$) decaying into $J/\psi\ \pi^+\pi^-$ [4]. Recently Belle reported the observation of $Y(3940) \to J/\psi\ \omega$ in $B^+ \to Y(3940)\ K^+$ decays [5].

All observed resonances – from $\eta_c(2S)$ to $Y(3940)$ – are difficult to reconstruct without the constraints provided by B decays, as they decay to high-multiplicity final states. B mesons also provide an excellent opportunity to test different hypotheses for the J^P quantum numbers of these resonances via decay angle analysis.

2 Observation of $X(3872)$ and it's properties

Just after the discovery of $X(3872)$ by Belle, this new state was confirmed by the CDF, D0 and BaBar collaborations [6]. Its mass was measured to be 3871.9 ± 0.5 MeV which is very close to the $D^0\bar{D}^{*0}$ threshold of 3871.3 ± 1.0 MeV. All these first measurements directly provide a lot of information on the $X(3872)$ properties [4]:

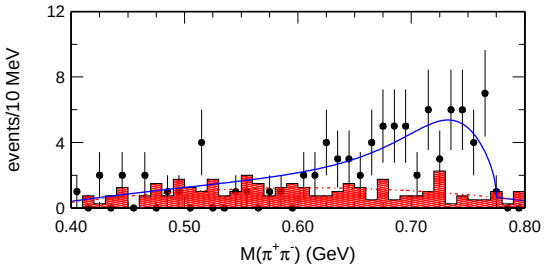

Figure 1: The invariant mass spectrum of $\pi^+\ \pi^-$ pairs from the $X(3972) \to J/\psi\ \pi^+\ \pi^-$ decay.

- the two pion mass from the $X(3872) \to J/\psi\ \pi^+\ \pi^-$ decay tends to peak near the ρ^0 mass, consistent with positive C-parity of the $X(3872)$;
- the decays $X(3872) \to \chi_{c1,2}\ \gamma$ are not seen; this likely excludes the $1^3D_{2,3}$ ($\psi_{2,3}$) assignment for the $X(3872)$;
- the decay $X(3872) \to D\bar{D}$ is suppressed or forbidden [2]; this, together with its narrow width ($\Gamma < 2.7$ MeV), suggests $J^P = 0^+, 1^-, 2^+, ...$ are ruled out;

CDF and D0 have measured the $X(3872)$ production properties to be very similar to those of the $\psi(2S)$ [6]. BaBar reported a null search for the charged $X(3872)$ partners in $B \to J/\psi\ \pi^+\ \pi^0\ K^+$ decays [7] and a null search for $X(3872) \to J/\psi\ \eta$ decay [8]. The former rules out the isovector hypothesis and the latter excludes the presence of gluonic degrees of freedom in the $X(3872)$ wave function.

Fig. 1 shows the $M(\pi^+\ \pi^-)$ spectrum from the updated analysis of $X(3872) \to J/\psi\ \pi^+\ \pi^-$ decays by Belle (253 fb^{-1}). The ρ^0 signal is strong and supports $C(X(3872)) = +1$.

Recently Belle has found evidence for another decay mode of $X(3872)$: $X(3872) \to J/\psi\ \omega^*$ where ω^* is virtual and reconstructed in the $\pi^+\ \pi^-\ \pi^0$ channel. According to Swanson's model [9], this observation supports the $D^0\bar{D}^{*0}$ molecular interpretation of $X(3872)$. The full set of the most recent Belle results on the $X(3872)$ properties can be found elsewhere [10].

3 Observation of $Y(3940)$

By analyzing exclusive $B^+ \to J/\psi\ \pi^+\ \pi^-\ \pi^0\ K^+$ decays Belle observed a new resonance $Y(3940)$ decaying to $J/\psi\ \omega$ [5]. Fig. 2 shows the $M(J/\psi\ \omega)$ distribution for the B-meson candidates. The curve in Fig. 2 (a) indicates the result of a fit with only a phase-space-like two-body threshold function. The curve in Fig. 2 (b) shows the result of a fit that includes an S-wave Breit-Wigner resonance term. The mass and width of $Y(3940)$ were measured to be $3943 \pm 11 \pm 13$ MeV and $87 \pm 22 \pm 26$ MeV, respectively. The observed state is above the $D\bar{D}^{(*)}$ threshold and would decay predominantly to $D\bar{D}$ and/or $D\bar{D}^*$ if it is a $c\bar{c}$ charmonium. In contrast, for a $c\bar{c} - gluon$ hybrid the open charm decay modes are suppressed or forbidden. So the observed $Y(3940)$ is a possible candidate for the first $c\bar{c} - gluon$ hybrid state.

4 Search for $B^+ \to h_c K^+$

The 1^1P_1, $J^P = 1^{+-}$ h_c has for a long time been a missing state. Recently CLEO reported the observation of h_c in $\psi(2S) \to h_c\ \pi^0$, $h_c \to \eta_c\ \gamma$ decays [11]. The mass was measured to be $3524.4 \pm 0.6 \pm 0.4$ MeV - in agreement with theoretical expectations that the $M(h_c)$ is close to the c.o.g. of of the $< 1^3P_J >$ triplet.

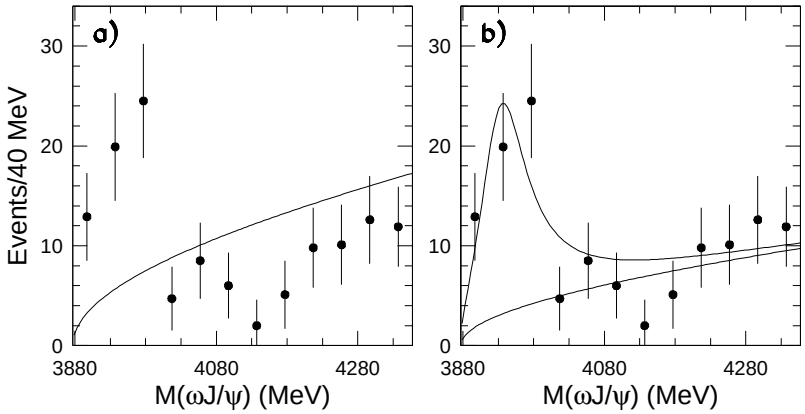

Figure 2: The invariant mass spectrum of $J/\psi\ \omega$ combinations from the $B^+ \to J/\psi\ \omega\ K^+$ decay. The curve in (a) indicates the result of a fit with only a phase-space-like two-body threshold function. The curve in (b) shows the result of a fit that includes an S-wave Breit-Wigner resonance term.

Belle searched for h_c production in exclusive $B^+ \to h_c\ K^+$, $h_c \to \eta_c\ \gamma$ decays. Fig. 3 shows the $M(\eta_c\ \gamma)$ for the B-candidates. No evidence for a signal around the CLEO h_c mass is seen. Belle set an upper limit for $\mathcal{B}(B^+ \to h_c\ K^+) \times \mathcal{B}(h_c \to \eta_c\ \gamma)$ that is less than 1.5×10^{-4} for $M(h_c) \sim 3520$ MeV [12].

5 Study of $D_{sJ}(2317)$ and $D_{sJ}(2460)$

The $D_{sJ}(2317)^{*+}$ and $D_{sJ}(2460)^+$ mesons were observed by BaBar [13] and CLEO [14]. Belle confirmed these states and observed their production in exclusive $B \to D_{sJ}^{*+}\bar{D}^{(*)}$ decays [15]. The observation of these decays allowed us to perform decay angle analysis. Belle data support $J = 0$ for $D_{sJ}(2317)$ and $J = 1$ for $D_{sJ}(2460)$ [16].

6 Summary

B mesons provide a clean environment for the observation of yet-unseen charmonia and other new unexpected resonances and the understanding of their properties.

The nature of new resonances $X(3872)$ and $Y(3940)$ remains unclear so far. They could be either $c\bar{c}$ states or exotic hadrons: $D^0\bar{D}^{*0}$ molecular ($X(3872)$) and $c\bar{c} - gluon$ hybrid ($Y(3940)$).

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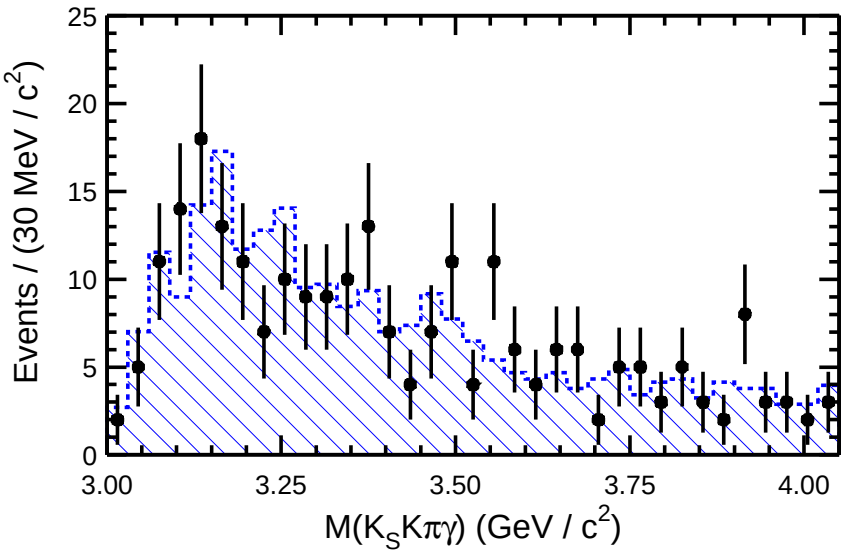

Figure 3: The invariant mass spectrum of $\eta_c\ \gamma$ for the $B^+ \to \eta_c\ \gamma\ K^+$ candidates.

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